Numerical Studies of Rough Surface Scattering Models

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Thrust Category: Shallow-Water Acoustics

LONG-TERM GOALS

To develop a practical set of rough surface scattering strength equations for use in real-world Navy applications.

OBJECTIVES

To examine and develop theoretical surface scattering models that accurately predict acoustic wave scattering at the air-sea interface and at the ocean-bottom interface.

APPROACH

We have focused our attention on the development and examination of two theoretical models, the small slope approximation (SSA) and the nonlocal small slope approximation (NLSSA). This year development of the SSA has been for Biot theory. The initial work was done by Taiqian Yang, an assistant professor at Central Washington University and a former Ph.D. student of the PI, and recently the work has been continued by Cristina Fetche, a current Ph.D. student of the PI, under the supervision of the PI. Development of the NLSSA has been for scattering at low forward grazing angles for the air/sea interface problem. This work has been done by the PI.

WORK COMPLETED

Considerable work was done on the SSA for Biot theory. Since we were unable to find anything in the published literature on rough surface scattering models for Biot theory, all the underlying rough surface scattering equations had to be obtained prior to derivation of the SSA equations. This was done with the assistance of some unpublished notes by Jim Grochocinski of Corning who had worked previously with Darrell Jackson of the University of Washington Applied Physics Laboratory. These notes and Jim's comments helped a great deal and allowed us to derive the underlying equations more quickly than we otherwise could have done. The rough surface scattering equations for the SSA were then derived, followed by derivation of the lowest-order SSA reflection coefficient, backscattering coefficient, and scattering strength. This past summer, code was written and numerical results were obtained for the reflection coefficient and backscattering coefficient.

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Rederivation of the NLSSA scattering strength integrals was accomplished using the approximation to the NLSSA formulated earlier. Code was then written to obtain numerical results for the approximate NLSSA scattering strength for a Gaussian surface roughness spectrum.

RESULTS

The numerical results obtained for the reflection coefficient and for the backscattering cross section using the lowest-order SSA for Biot theory were compared with those of perturbation theory. The results agreed well in what is considered to be the region of validity for perturbation theory; they differed as the roughness was increased, but since no exact results are available for Biot theory, it is not known how accurate the SSA results are. However, to our knowledge, these are the first results that will be presented for rough surface scattering using Biot theory. Numerical results for the approximate NLSSA scattering strength were obtained at low forward grazing angles. Numerical difficulties made it impossible to obtain results for the original expression for the NLSSA without the approximation. Moreover, the results agreed well with exact results, indicating that the approximate NLSSA might prove to be useful for forward scattering.

IMPACT/APPLICATIONS

The development of approximate models that accurately predict wave scattering from rough surfaces is important in a number of Navy applications. For example, rough surface scattering models are needed in the simulations used by torpedo guidance and control personnel to test torpedoes. Another application for which rough surface scattering is critical is the detection of underwater mines, especially those buried in soft sediments. Other applications include ship wake detection, communications, and anti-submarine warfare. Of particular importance is that the models be as simple as possible while retaining the physical information necessary for the application.

TRANSITIONS

Much of the knowledge we have gained has been disseminated via publications and conference presentations. Seminars have also been presented, one for the Washington State University physics department and one for researchers at the Applied Physics Laboratory. A search of the Science Citation Index on-line shows that previous ONR-sponsored work is being used by other researchers; it is believed that the current work will also be of use to others.

RELATED PROJECTS

This work is related to research in shallow water acoustics, high-frequency acoustics, and long-range propagation. The SSA Biot work is especially relevant to high-frequency, shallow water acoustics where the question of acoustic penetration into sediment is of much interest. The NLSSA work is relevant to long-range propagation since it attempts to model accurately scattering in the forward direction. Additionally, this work is related to that of several other ONR-sponsored researchers including Eric Thorsos and John Schneider.

PUBLICATIONS

1. Broschat, S.L., "Reflection loss from a 'Pierson-Moskowitz' sea surface using the non-local small slope approximation," IEEE Trans. Geosci. Rem. Sens., Vol. 37, No. 1, 632-634, Jan. 1999.

2. Broschat, S.L., "An approximation of the NLSSA scattering cross section," IEEE Antennas and Propagation Society International Symposium and URSI Radio Science Meeting, Salt Lake City, Utah, Jul. 2000.

3. Hastings, F.D., J.B. Schneider, S.L. Broschat, and E.I. Thorsos, "An FDTD method for analysis of scattering from rough fluid-fluid interfaces," to be published in IEEE Journal of Oceanic Engineering.

4. Fetche, C., T.Q. Yang, and S.L. Broschat, "The small slope approximation for acoustic scattering from a rough interface between a fluid and a fluid-saturated porous solid," 140th Meeting of the Acoustical Society of America, Newport Beach, California, Dec. 2000; J. Acoust. Soc. Am., Vol. 108, No. 4, Pt. 2, Nov. 2000.

5. Broschat, S.L., "Numerical results for an approximate form of the non-local small slope approximation scattering strength," 140th Meeting of the Acoustical Society of America, Newport Beach, California, Dec. 2000; J. Acoust. Soc. Am., Vol. 108, No. 4, Pt. 2, Nov. 2000.